

Simulation of Interannual Variability in Solar Benchmark Reflectance And Comparison With Observation And OSSE

**Zhonghai Jin, Constantin Lukachin, Yolanda Roberts,
Bruce Wielicki, Daniel Feldman, and William Collins**

**CLARREO SDT Meeting
Washington, DC, October 15-17, 2013**

Objectives:

- 1) Understand the natural variability expected in the CLARREO solar benchmark reflectance spectra.
- 2) Evaluate the modeling ability to simulate the benchmark reflectance and its interannual variability in large climate domains.
- 3) Cross check the results from RT model, climate OSSE (Observing System Simulation Experiment), and observations for consistency.

Observation data: SCIAMACHY radiance and solar irradiance (2003-2010).

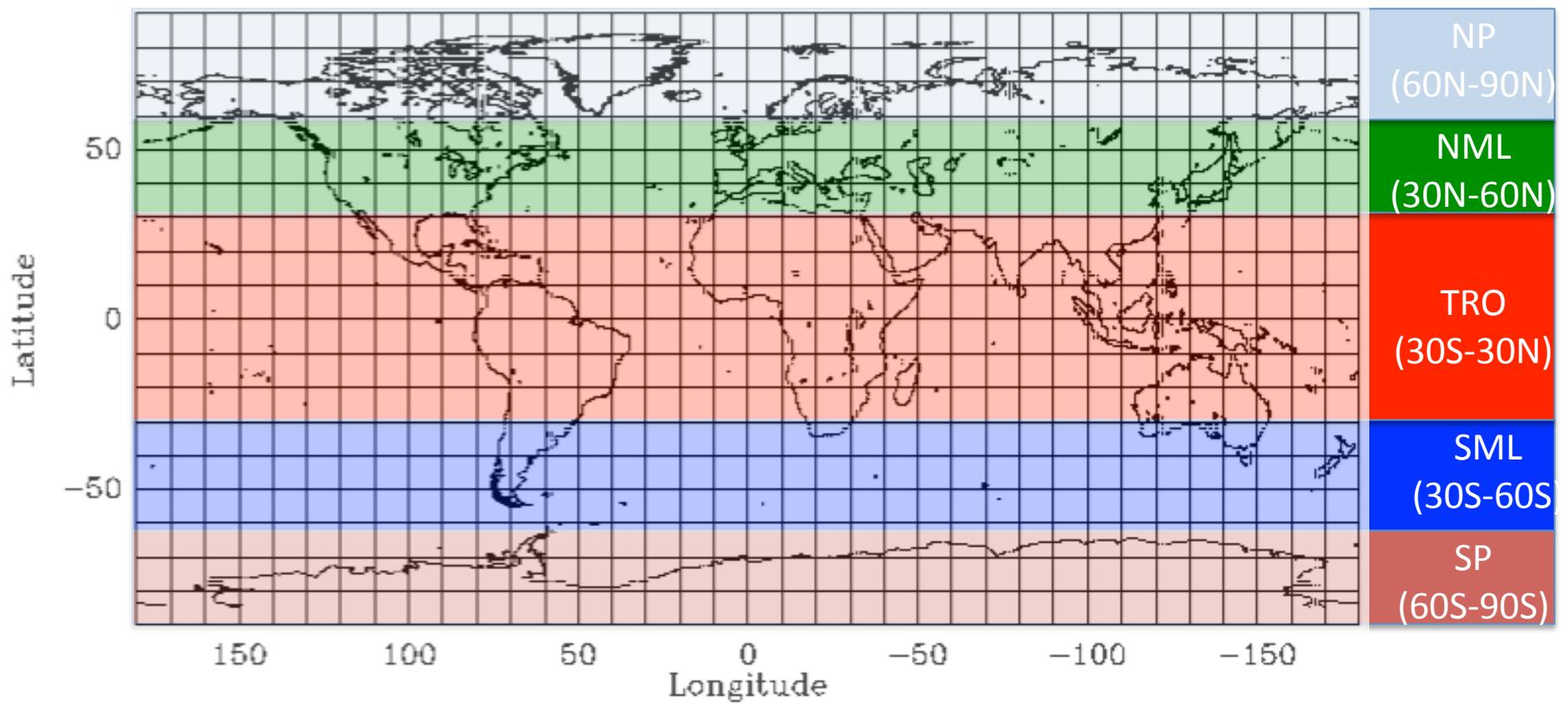
Spectral range: 300-1750 nm; resolution: 1 nm.

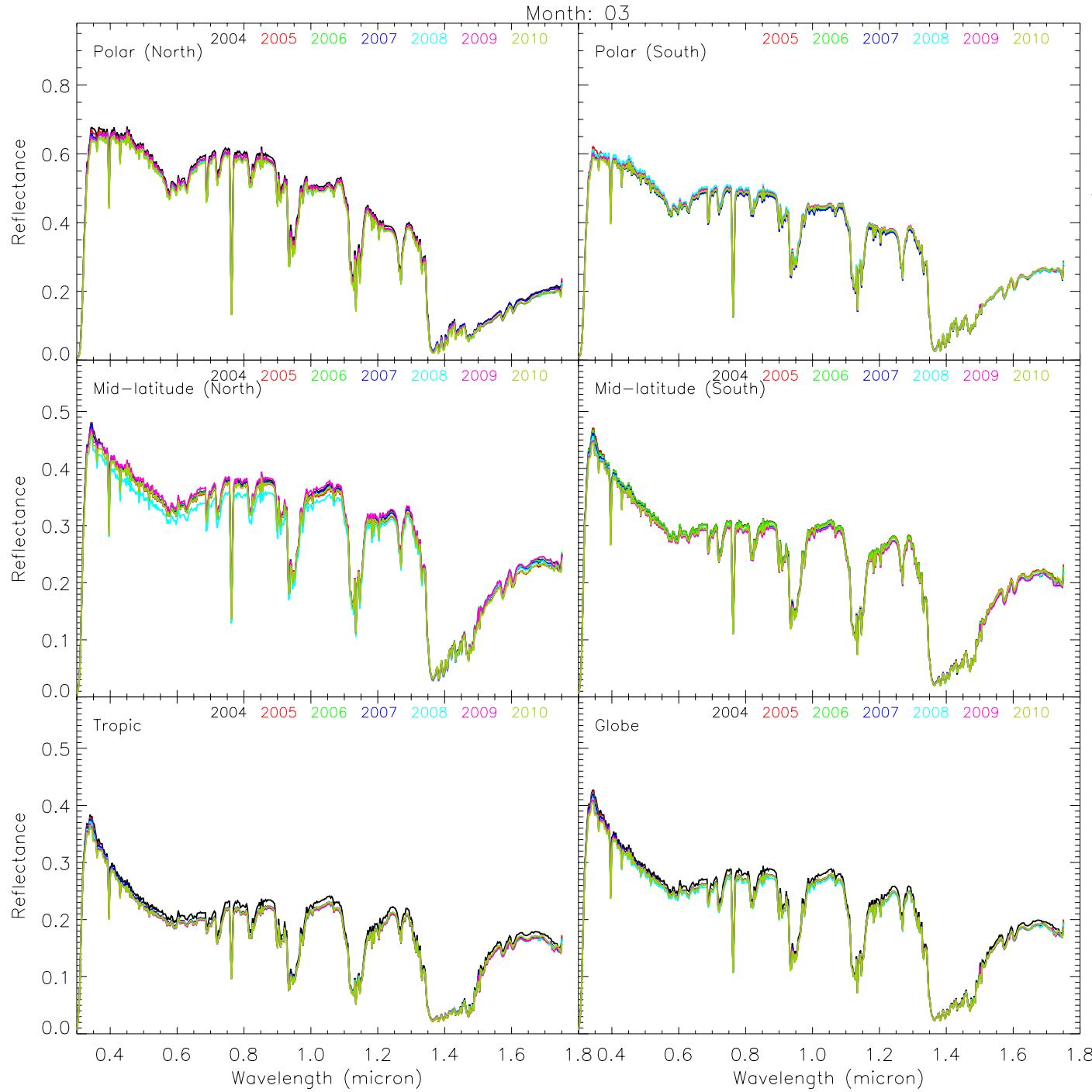
RT model: COART-MODTRAN with input parameters from CERES SSF, MODIS, SeaWiFS, and SMOBA.

Climate OSSE: MODTRAN with input parameters from climate model simulations.

CLARREO's climate benchmark concerns radiation spectra averaged over large space and time scales. So the measured and modeled reflectance spectra are averaged over the 5 large latitude regions and globe for comparison.

Five latitude regions





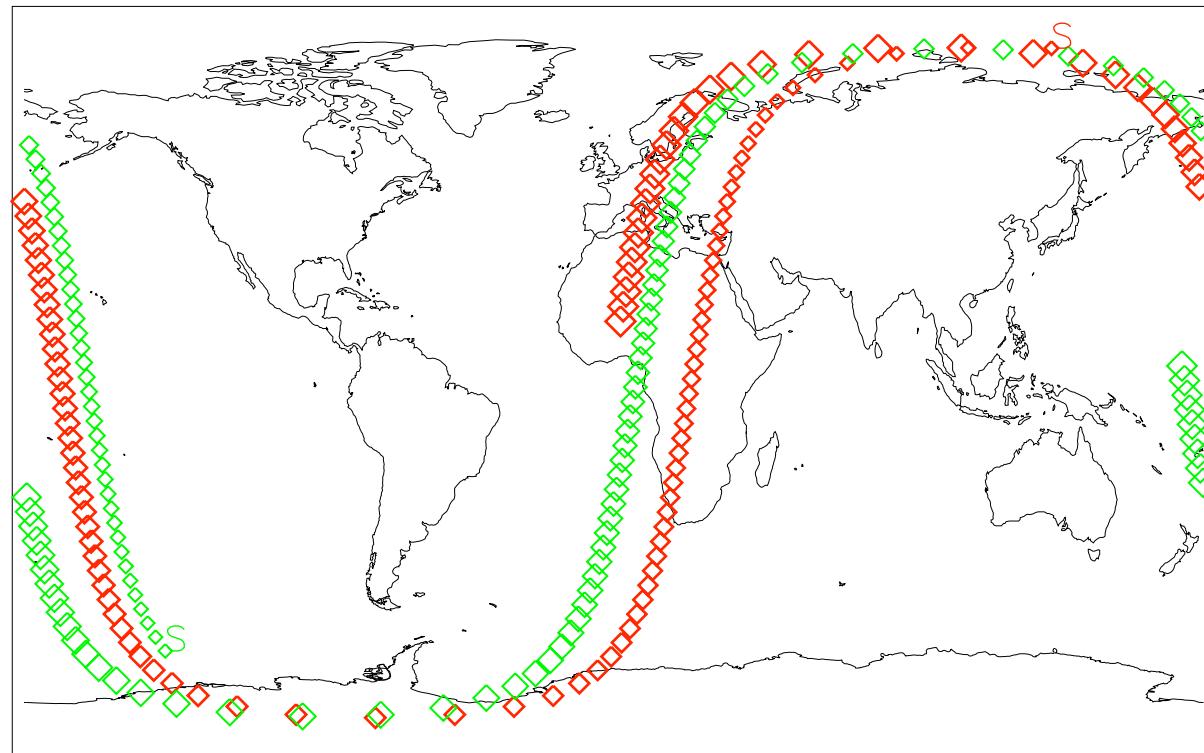
An example of SCIAM measured solar reflectance averaged to the 5 latitude regions and globe in one month.

(Each panel is for a different region, each color is for a different year.)

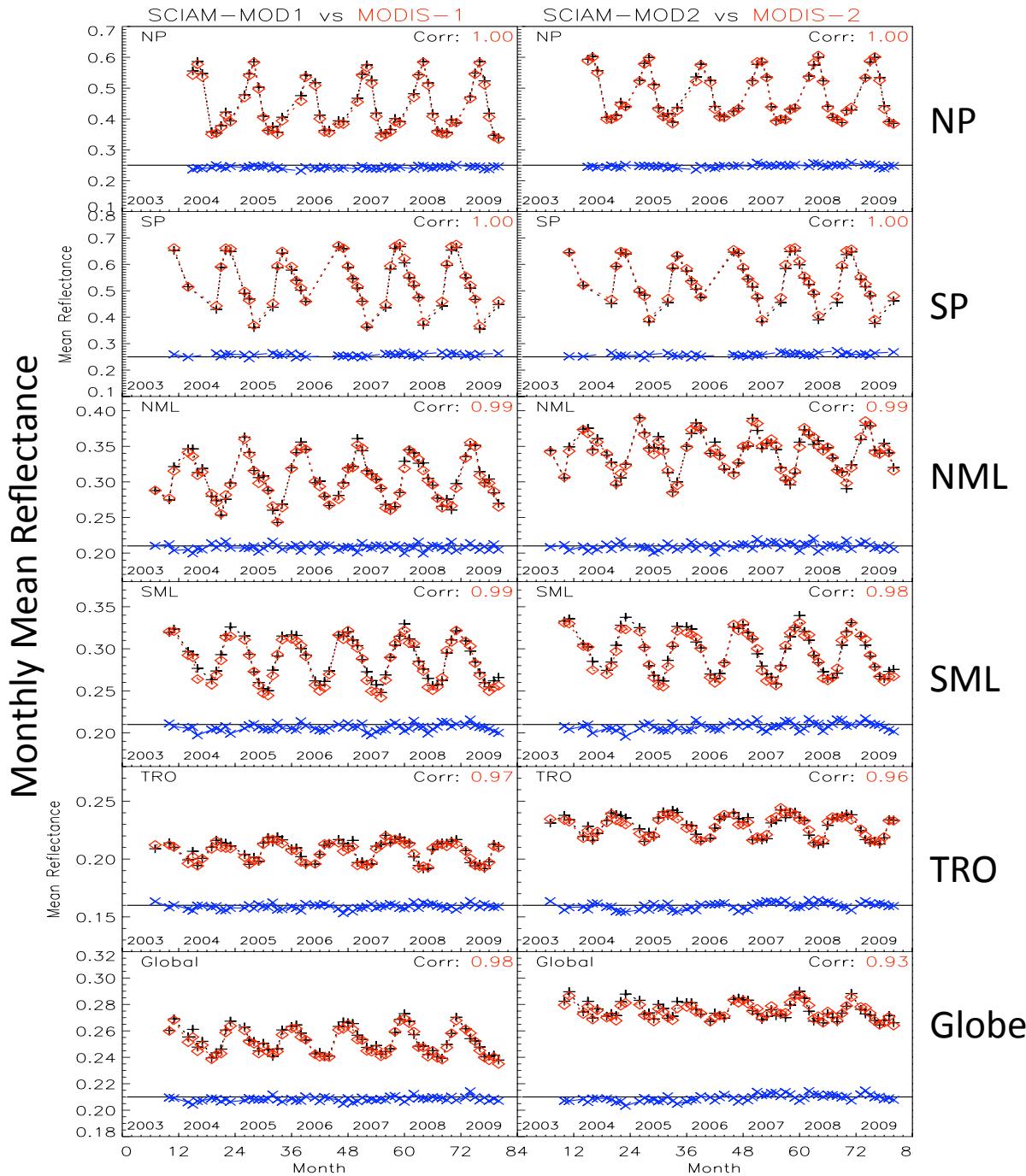
Envisat and Terra have similar sun-synchronous orbit:

Satellite!@	Altitude	Inclination	Period	Equator crossing
Envisat	799.8 km	98.6°	100.6 min	10:00 LST
Terra	705 km	98.2°	98.8 min	10:30 LST

Terra and **Envisat** ground tracks: 8:30 – 10:30, 09-30-2011



The average time difference of overpass is about 30 min.
(This **doesn't** mean that the measurements from them are nearly co-incident or co-located.)



When averaged to large domains, the two like reflectances from SCIAM and MODIS are nearly the same!

NP

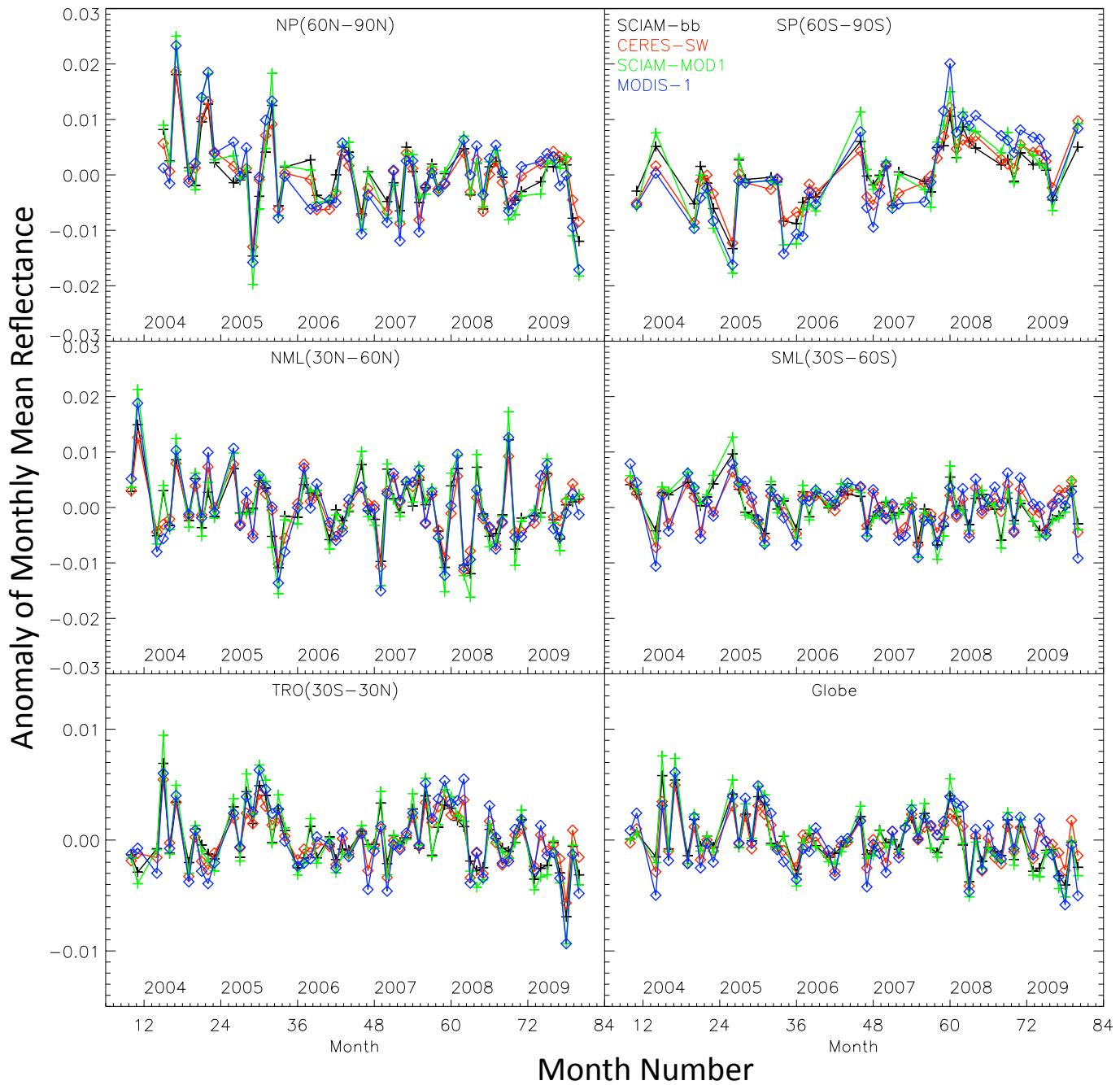
SP

NML

SML

TRO

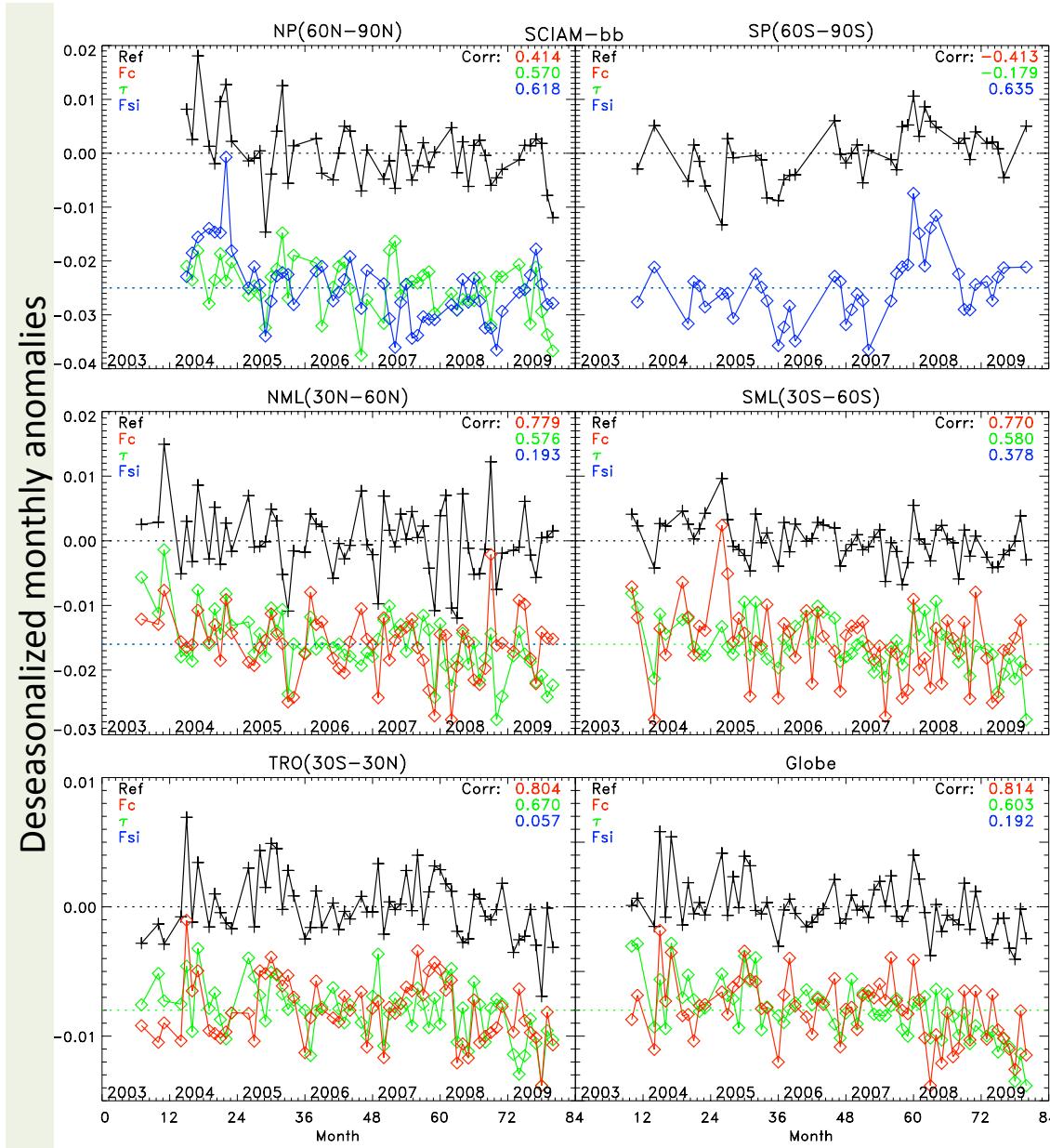
Globe



**Deseasonalized
monthly mean
reflectance
anomalies.**

SCIAM-bb
CERES-SW
SCIAM-MOD1
MODIS Ch1

**Averaged in the large
climate domains, the
anomalies are similar
and well correlated too!**

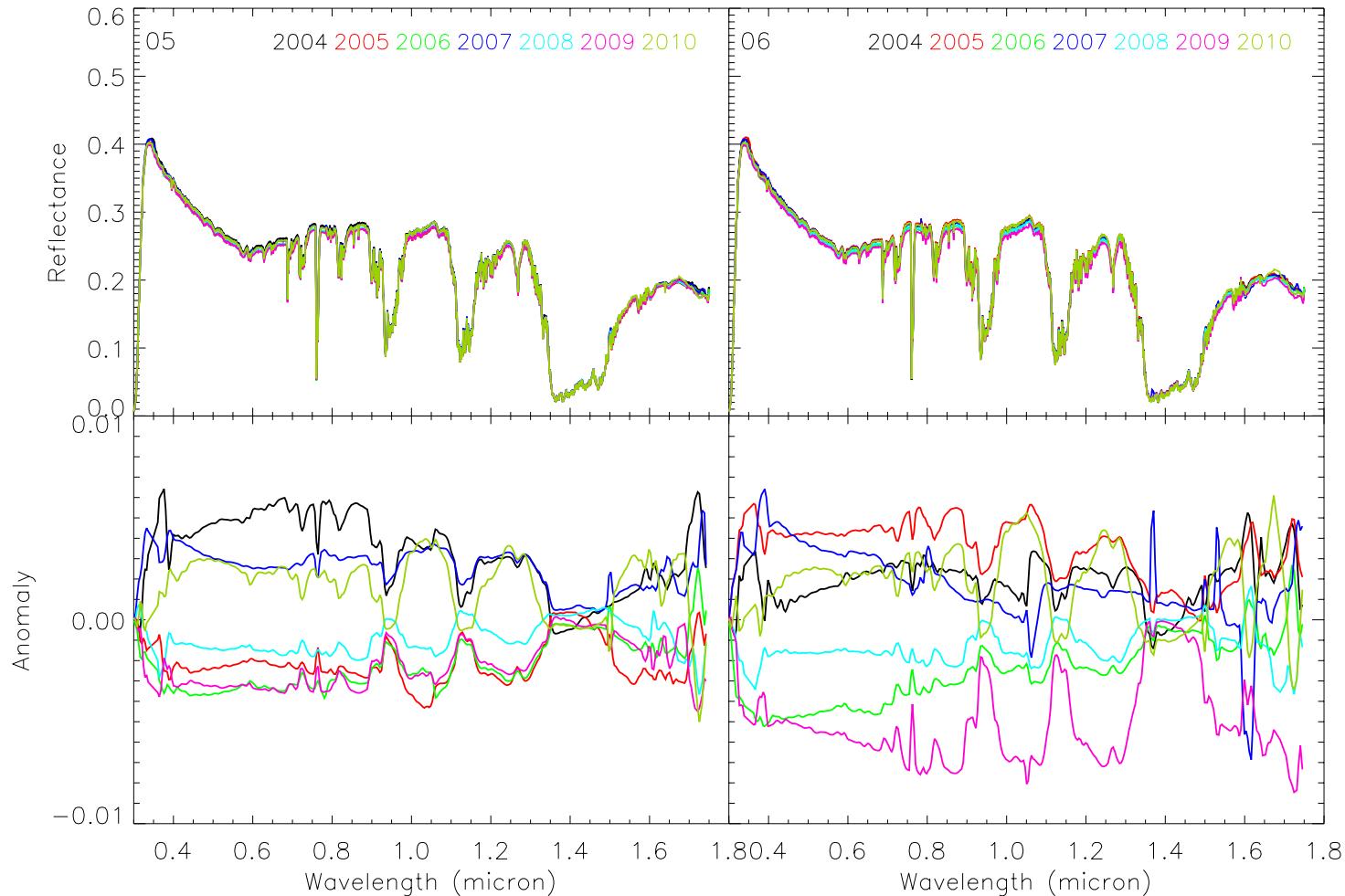


Correlations of
reflectance variation
with
cloud fraction (F_c),
optical depth (τ),
Snow/sea ice fraction (F_{si})

The interannual difference in SCIAM reflectance is also correlated with the interannual variations in the atmospheric/surface properties.

Jin, Z., et al , Correlation between SCIAMACHY, MODIS, and CERES reflectance measurements: Implications for CLARREO, *J. Geophys. Res.*, 117, D05114, 2012.

Can the large domain averaged reflectances and their interannual differences from SCIAM be simulated from the instantaneous satellite retrievals from MODIS/CERES?



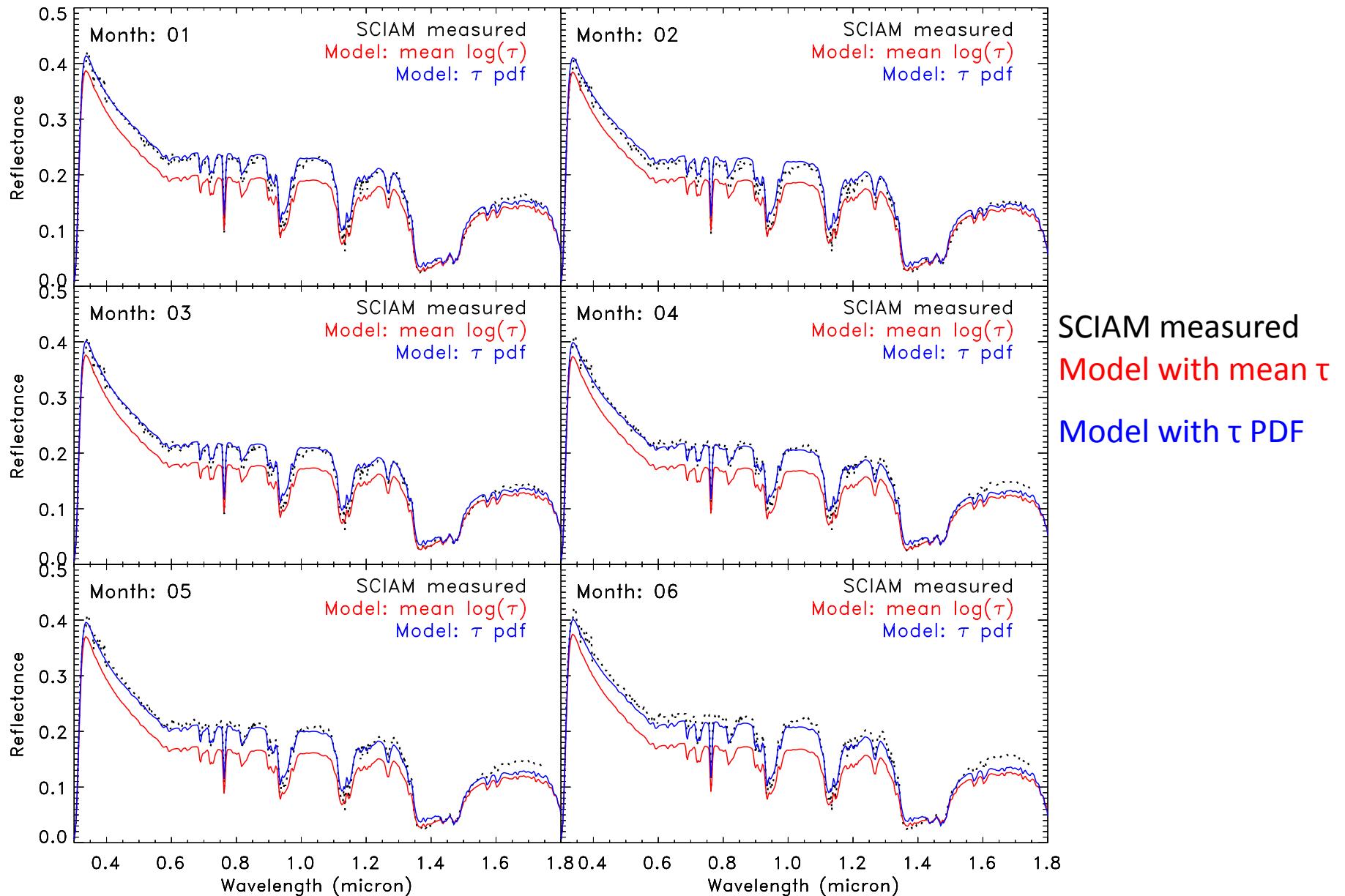
**Ocean only
here and
hereafter**

**An example of monthly/globally mean reflectance and anomaly from SCIAM.
(Left column is for May and the right is for June. Each color is for a different year).**

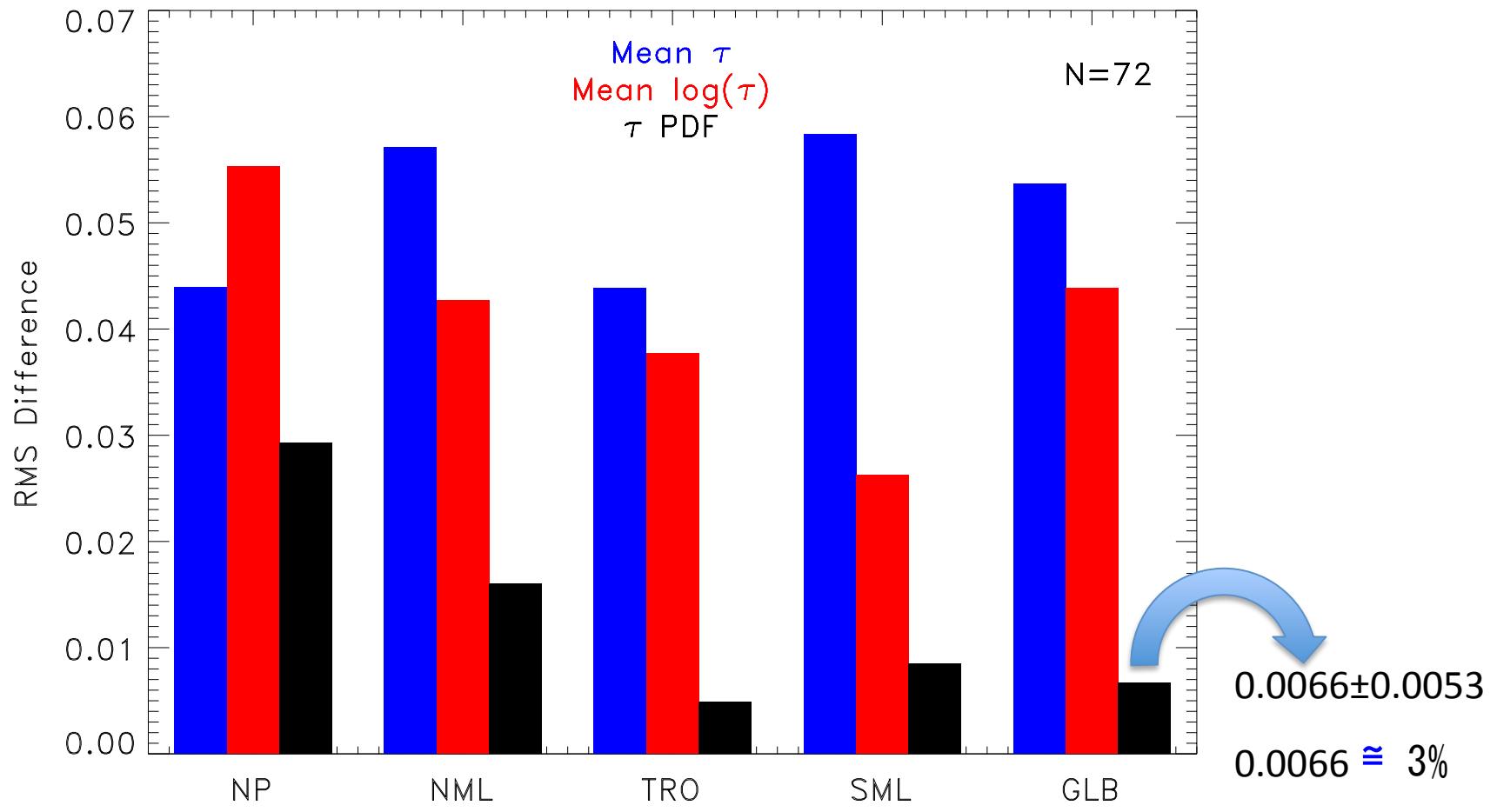
Because the model simulation uses instantaneous data from CERES/MODIS, it is impractical, if not impossible, to simulate the mean spectral radiance over large climate domains by explicit RT computations for each individual satellite footprint.

To simplify the RT calculation, we have recently developed a scheme based on the cloud probability distribution function (PDF) to efficiently and accurately calculate the large domain-averaged radiance/reflectance using a large volume of instantaneous satellite data.

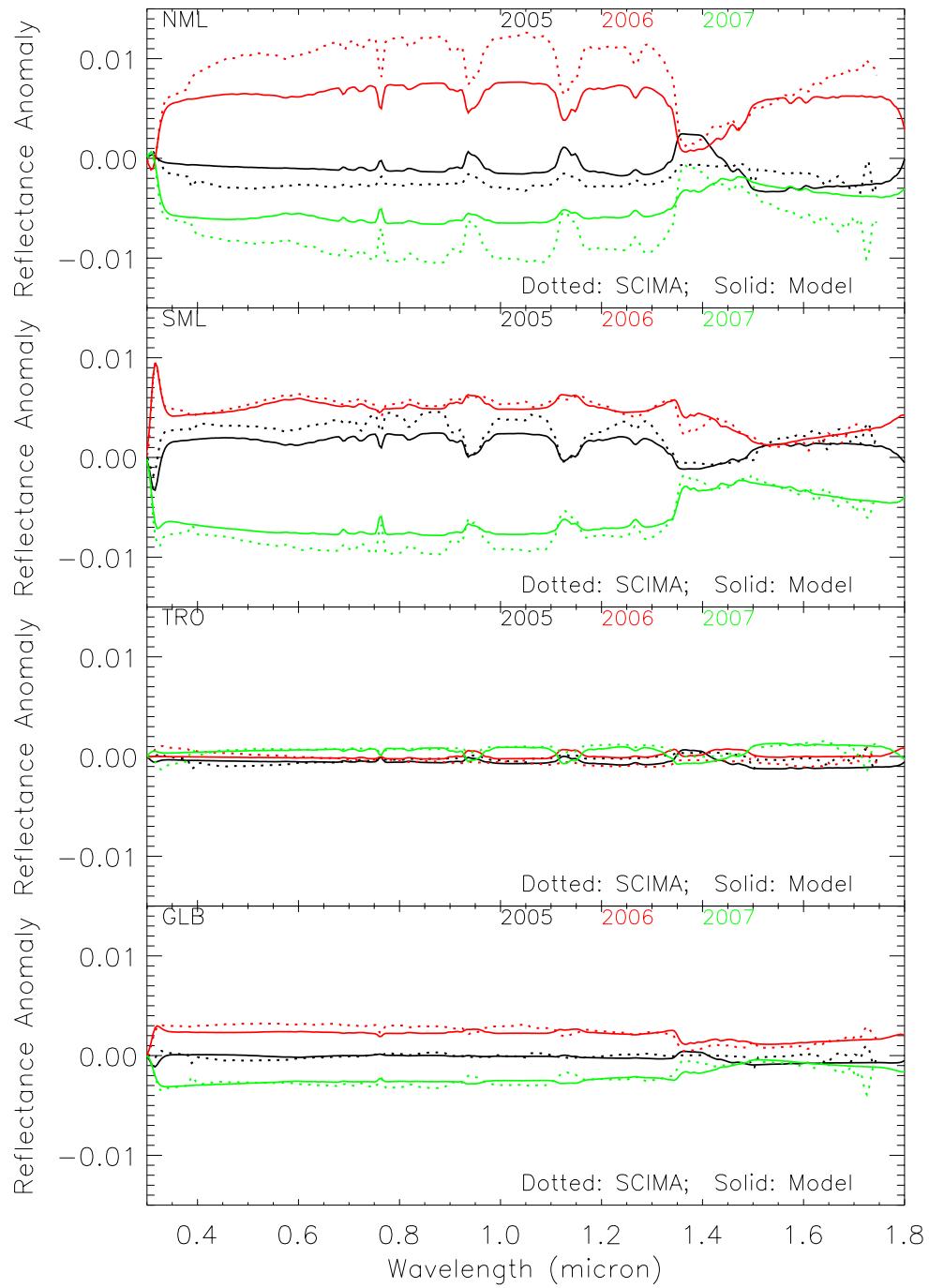
Jin, Z., et al., An efficient and effective method to simulate the earth spectral reflectance over large temporal and spatial scales, *Geophys. Res. Lett.*, 40, 374–379, 2013.



Comparison of observed and calculated monthly and globally averaged spectral nadir reflectance (ocean only).

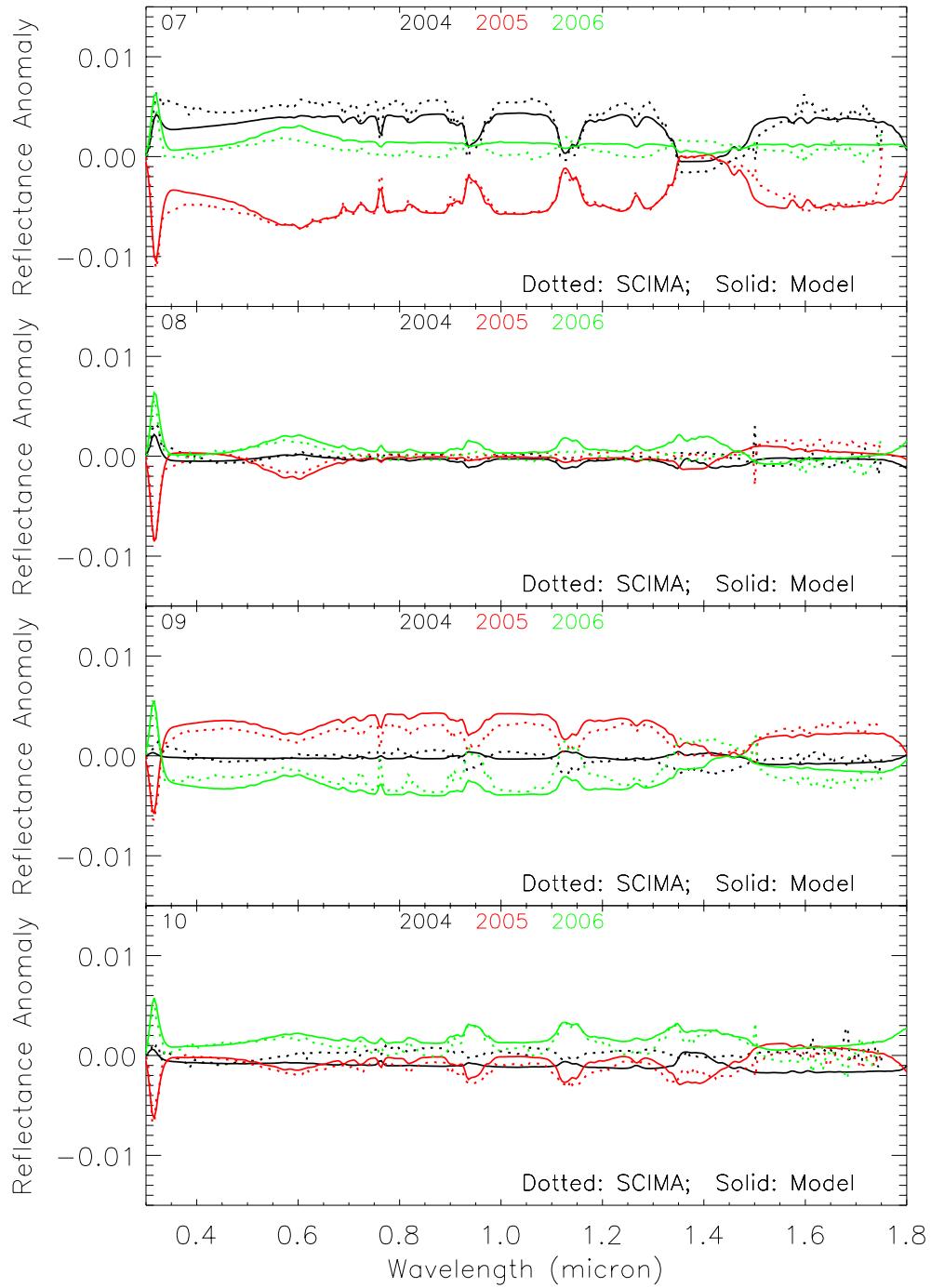


The RMS model discrepancy in the monthly mean reflectance in the five latitude regions (based on the results in the 72 months from 2004 to 2009). Each color bar represents a RMS error for a different modeling approach.



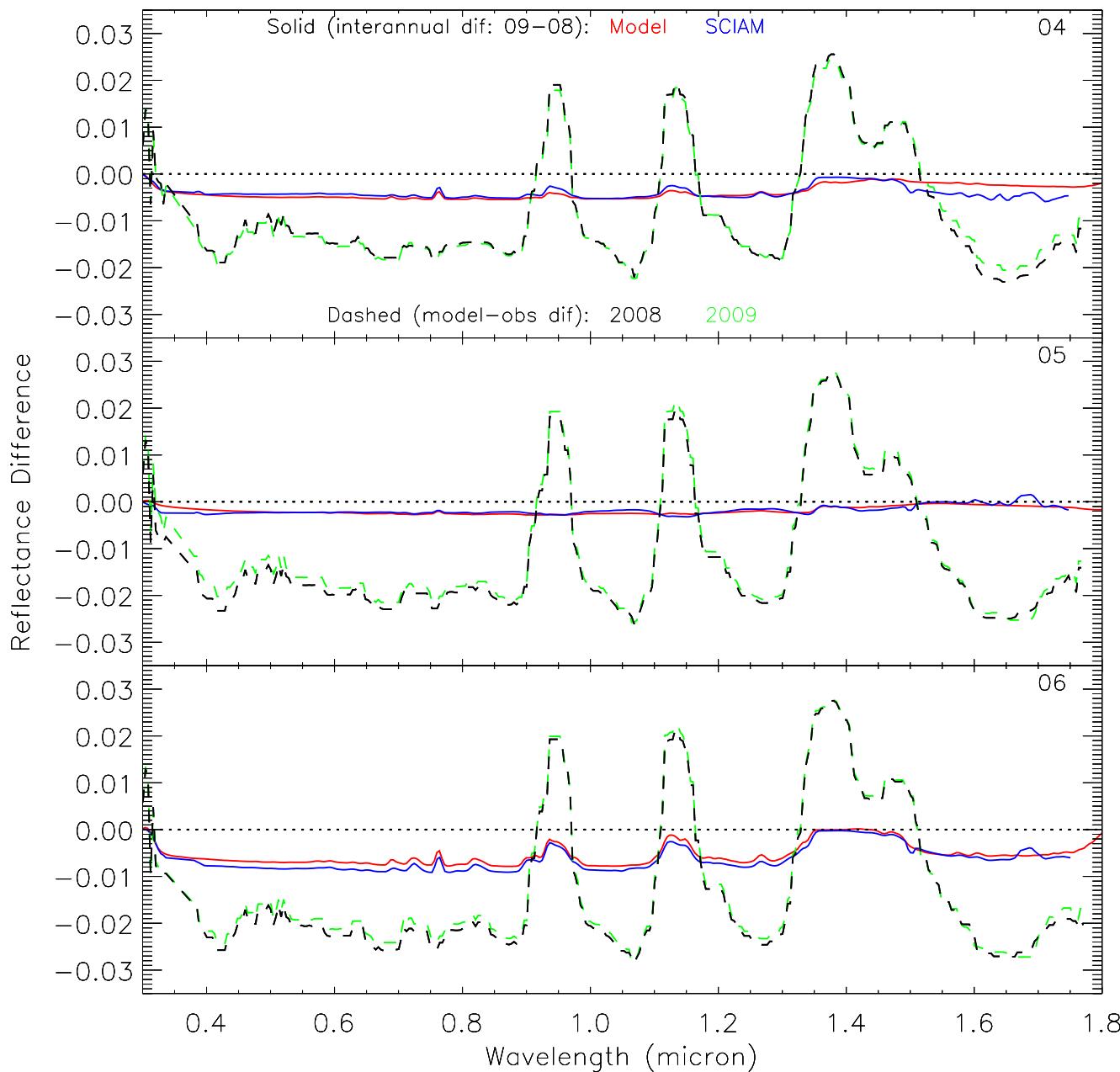
Comparison of the monthly mean reflectance anomalies between SCIAM measurements and model.
 (In the same month but different regions. One panel for one region and one color for one year.)

Dotted: SCIAM
 Solid: Model



Comparison of the global monthly mean reflectance anomalies between SCIAM measurements and model.
 (In the same region but different months. One panel for one month and one color for one year.)

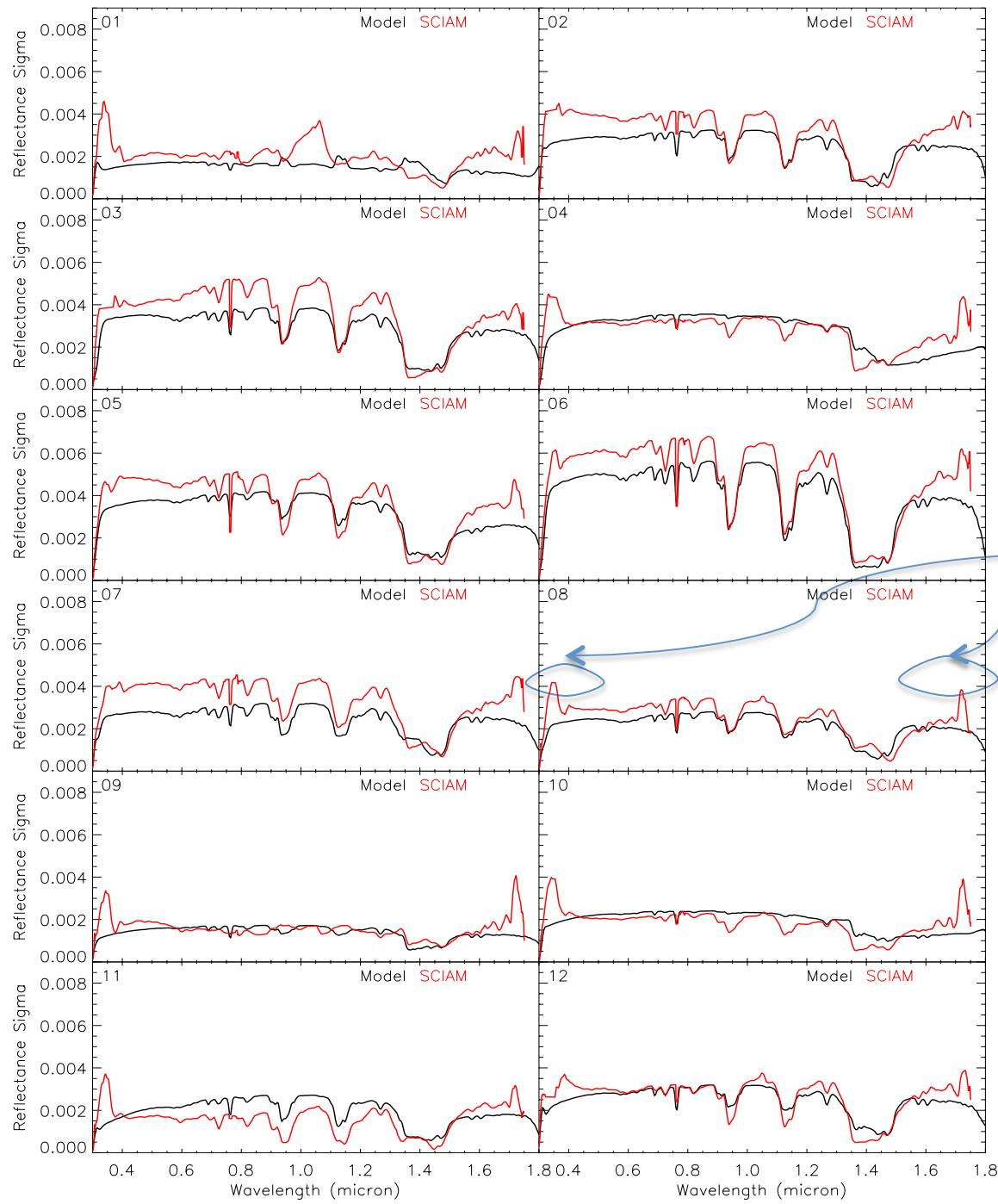
Dotted: SCIAM
 Solid: Model



How the RT model can simulate the anomaly that could be smaller than the modeling error?

An example to show the interannual difference and the modeling error in the monthly and globally mean reflectance. Each panel is for a different month.

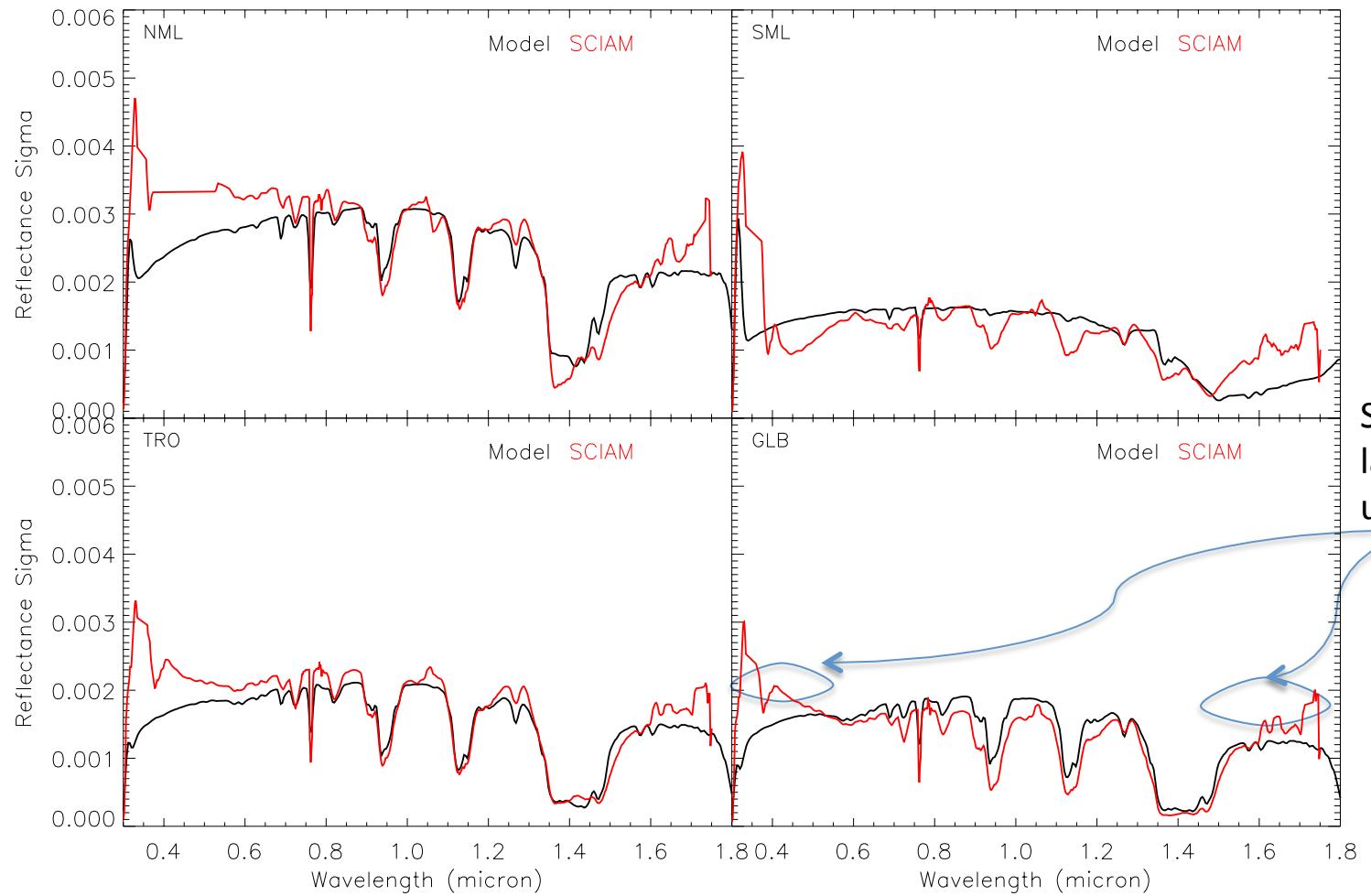
Solid line: interannual difference (2009-2008): blue for SCIAM and red for model;
 Dashed line: model discrepancy from data (i.e., model error): red for 2008 and blue for 2009.



**1 σ of the monthly mean
global reflectance across
all years (2004-2010) from
SCIAM and model.**

One panel for one month.

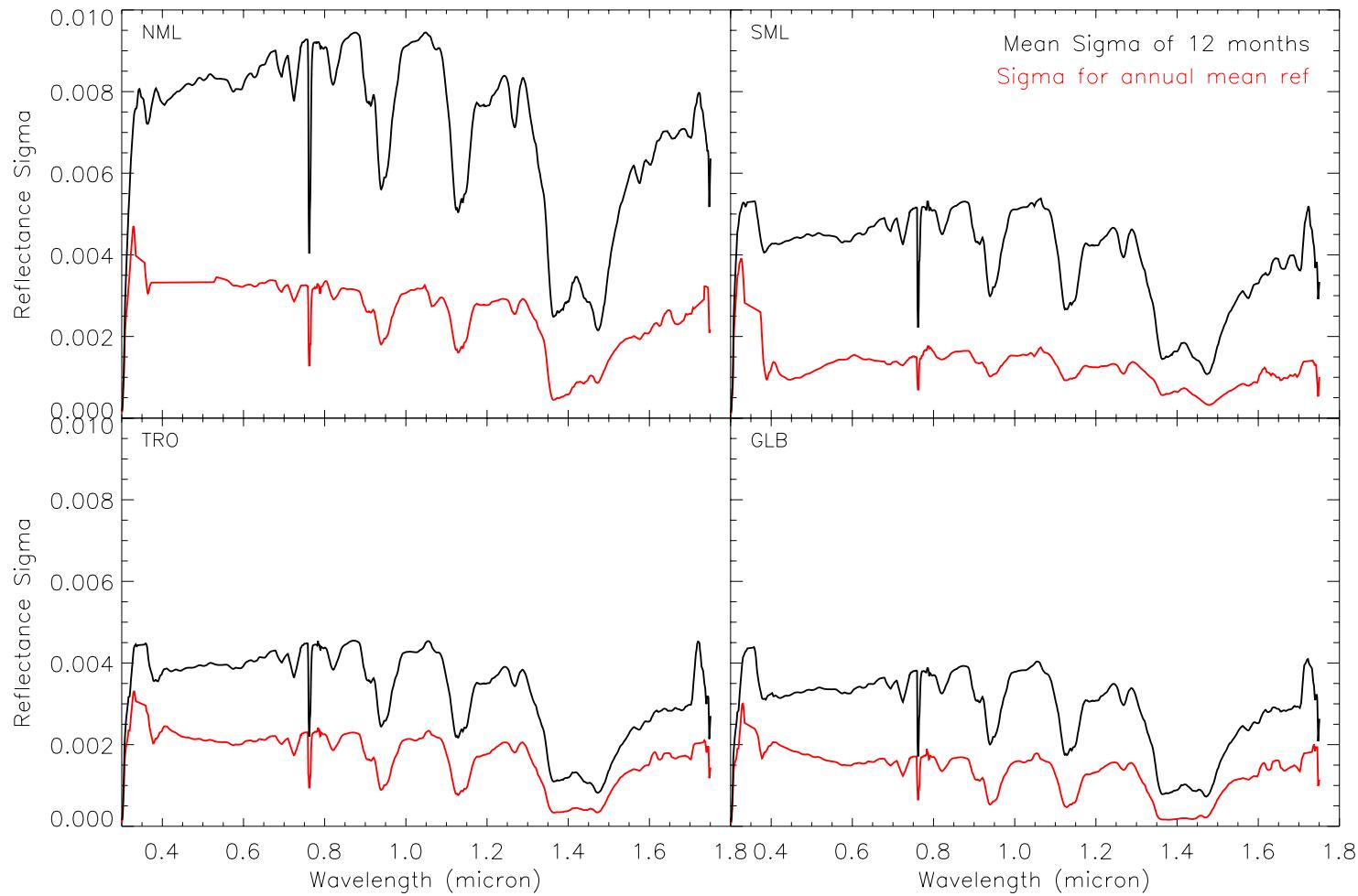
Spectral ranges with
large measurement
uncertainty.



Spectral ranges with
large measurement
uncertainty.

**The interannual variability (σ) in the annual mean reflectance
from SCIAM and model.**

Each panel shows a different region.



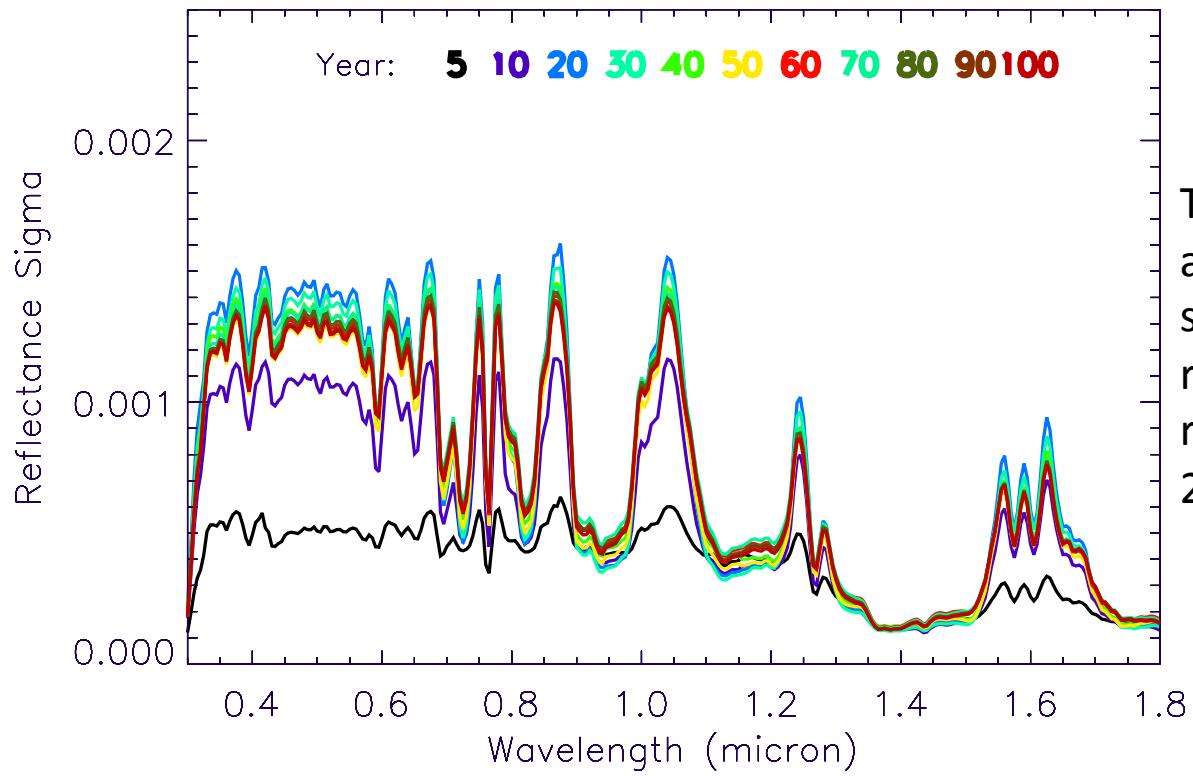
Comparison of the spectral reflectance σ between the monthly mean and the annual mean in different regions.

Each panel shows a different region.

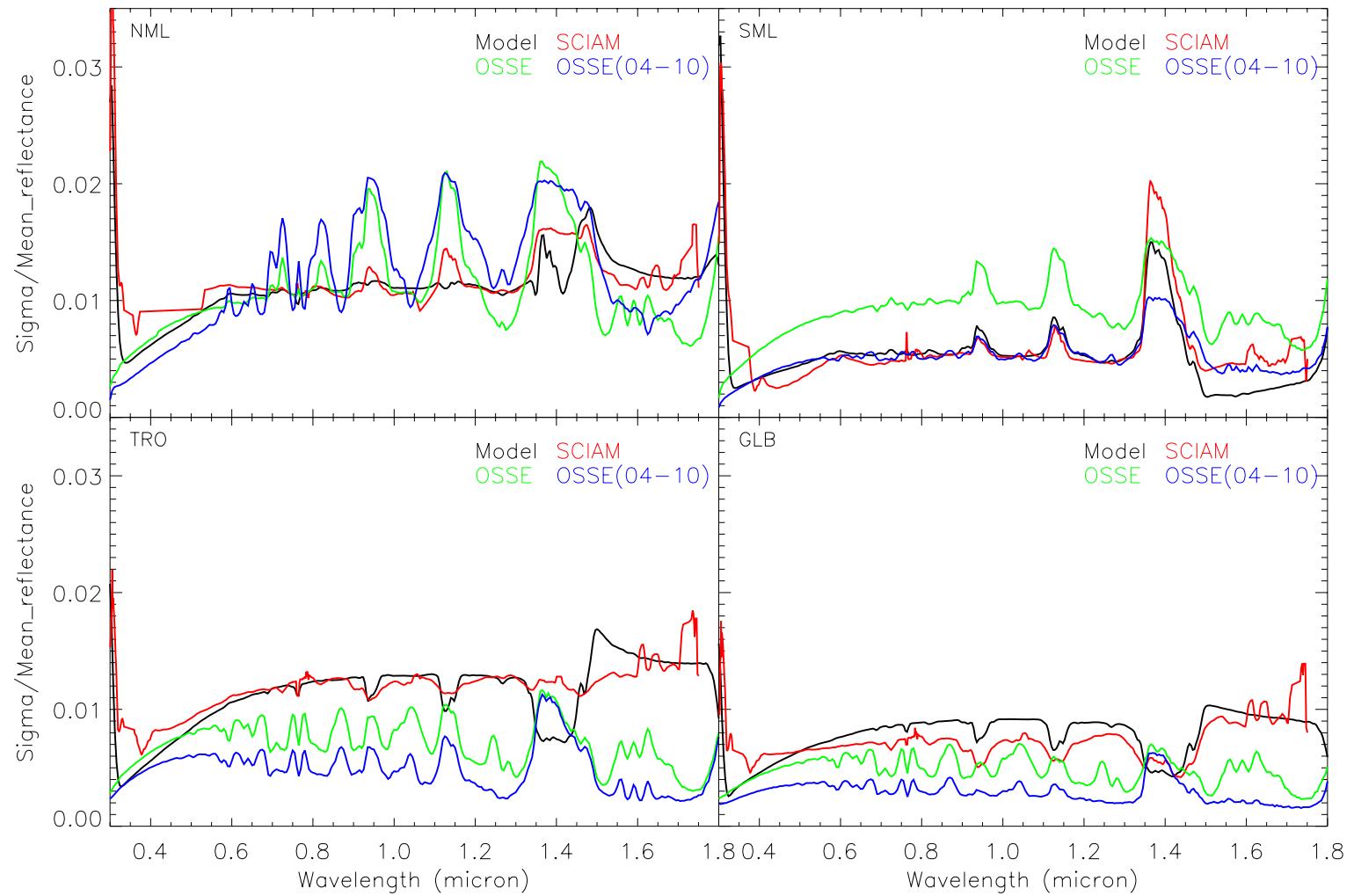
Because of the limited time period for the observational data, the climate trend has negligible impact on the interannual variability shown above (from data and model). For the same reason, the variability may not represent the stabilized real natural variability either.

Unlike the simulation based on physical observations, the OSSE calculates the shortwave spectra based on climate model simulations projected for certain climate change scenarios and therefore, it has no limitation on time.

Comparing the results from observations, RT model, and climate OSSE would help us to find out if the observations under limited time period can represent the real natural variability and if the OSSE spectra capture the natural variability in existing satellite-based shortwave reflectance.



The variation σ in the global and annual mean reflectance spectra simulated by OSSE for various time ranges. The colored numbers represent the years starting from 2000.



Comparison of the normalized σ (i.e., $\sigma/\text{reflectance ratio}$) between model, OSSE and SCIAM.

Summary

- The interannual variability of the solar spectral reflectance averaged over large spatiotemporal scales is examined through data and model.
- Such large domain averaged reflectances show small interannual variation, usually under few percent, depending on latitude region and spatiotemporal scale for averaging. The variability decreases as the temporal and spatial scales increase, for example, it is about 50% lower in the annual mean reflectance than that in the monthly mean.
- The interannual variability from observation in large climate domains also compares favorably with that from the climate OSSE based on climate model simulations; both show a variation σ of less than 1% of the mean reflectance across all spectra for global and annual average over the ocean.

- Although the interannual variation is usually less than the absolute accuracy of model calculation, the model simulated variability is consistent with measurements, because most of the modeling error in the large-domain-averaged reflectance is systematic and is canceled out in the interannual difference spectra.
- The modeling ability to simulate the interannual variation of the reflectance benchmark spectrum is a prerequisite for a successful climate attribution from observational benchmark data. Successful simulation of the interannual variation spectra is a step advance towards the solar fingerprinting through observational data.

Acknowledgement:

We thank the CERES team and DAAC at NASA Langley for the CERES SSF data, Sciamachy science team for the spectral solar radiance/irradiance data, and Dr. Sky Yang and Dr. Shuntai Zhou for the SMOBA data.